

CuCl/HCl Electrolyzer Kinetics for Hydrogen Production via Cu-Cl Thermochemical Cycle

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Hydrogen gas is a vital chemical for industrial processes that satisfy many growing needs in modern society. Currently hydrogen gas is used heavily in the petrochemical and agricultural industries. Hydrogen is a promising fuel for automotive and other applications. To meet these needs, the primary source of hydrogen gas production is from reforming fossil fuels. However, with the advent of climate change debates, global interest has increased for methods of hydrogen production not reliant on fossil fuels. Hydrogen production via a thermochemical cycle is one of the most promising methods for a sustainable source of hydrogen gas.

Thermochemical cycles utilize chemical reactions to thermally decompose water into hydrogen and oxygen gases. With the exception of water, the chemicals used within the cycle are recycled for continuous usage. Among many proposed thermochemical cycles, the Cu-Cl hybrid thermochemical cycle is one of the most promising due to moderate temperature requirements and simplicity when compared to many of the other theoretically possible cycles. A key component for the CuCl hybrid thermochemical cycle is a CuCl/HCl electrolytic cell. Previous studies have demonstrated the thermodynamic advantages of CuCl electrolysis when compared to water electrolysis. Specifically, this electrolytic process shows the experimental decomposition potential, E_d , of around 0.2 V (see Figure 1), which is about one order magnitude smaller than E_d of water electrolysis. However, to make the thermochemical process economically viable some improvements in materials of the CuCl electrolytic cell are needed.

This study demonstrates that a 50 % reduction in platinum catalyst is possible while operating with a current density of 0.55 A cm^{-2} at an applied cell potential of 0.7 V.

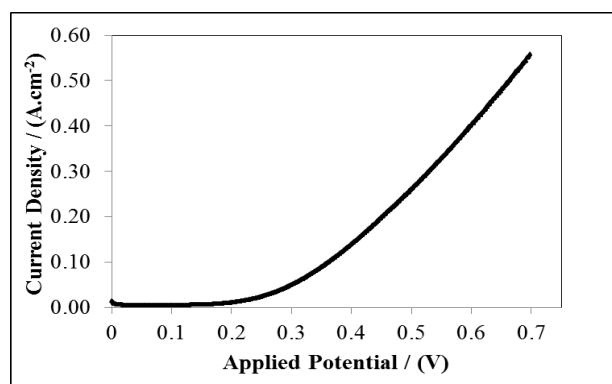


Figure 1. LSV for a CuCl electrolytic cell operating at 80 °C and 1 bar. ($0.4 \text{ mg Pt cm}^{-2}$ loadings on two 5 cm^2 carbon cloth electrodes, Nafion 117 membrane, anolyte of 2 mol CuCl(aq) in $7 \text{ mol L}^{-1} \text{ HCl(aq)}$, catholyte of 7 mol L^{-1} and flow rates of 400 mL/min).

Linear sweep voltammetry (LSV) (Figure 1), scanning electron microscopy (SEM) (Figure 2), and electrochemical impedance spectroscopy (EIS) (Figure 3), were used to characterize changes in kinetic parameters by alterations to catalyst application methods. SEM images were also used to observe the effect of different catalyst application methods on the effective electrode surface area. EIS tests over a range of polarizations were used to quantify electrochemical parameters and such as charge transfer resistance and ohmic resistance for different catalyst loading techniques. Electrochemical parameters from EIS were used to model the DC response of the CuCl electrolyzer and these results were compared with LSV data for verification. Information obtained from these analytical techniques was used to modify the catalyst application procedures to maintain high current density performance while reducing the total amount of catalyst needed.

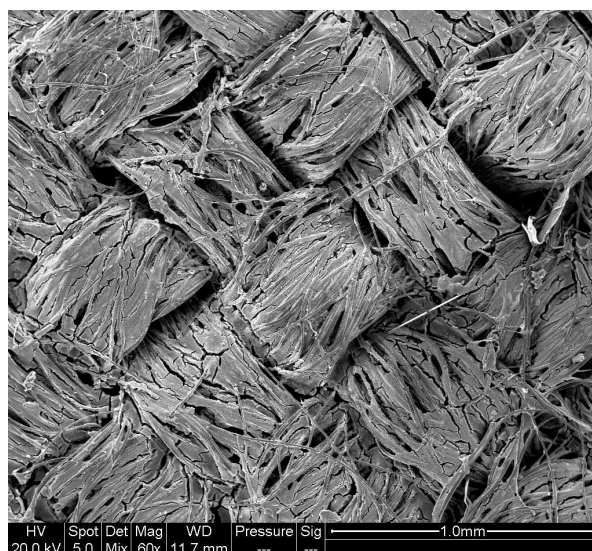


Figure 2. SEM with BSE Overlay for Used Electrode with Sprayed Catalyst Loading Technique.

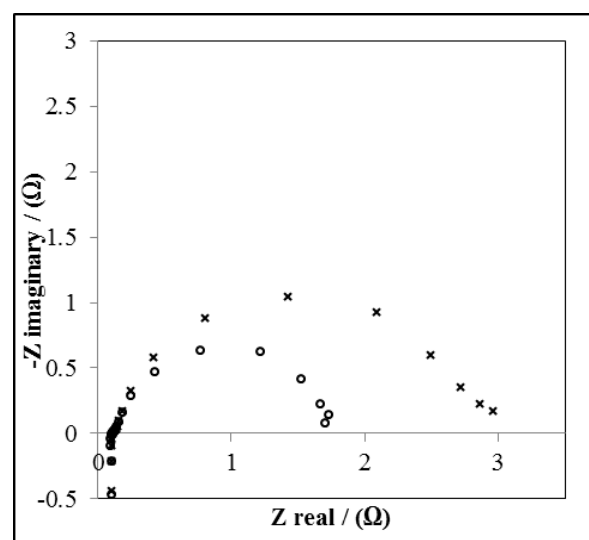


Figure 3. EIS data for two different cell assemblies at 30 °C and 1 bar. o = cell assembly one, x = cell assembly two. (EIS testing used 300 kHz to 3 mHz, 3 points per decade, with an AC potential 10 mV rms at an applied cell potential of 0.3 V.)

This research was supported by the U.S. Department of Energy through a subcontract with Argonne National Laboratory.